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# An overview on fish pathogens with special reference to aquaculture

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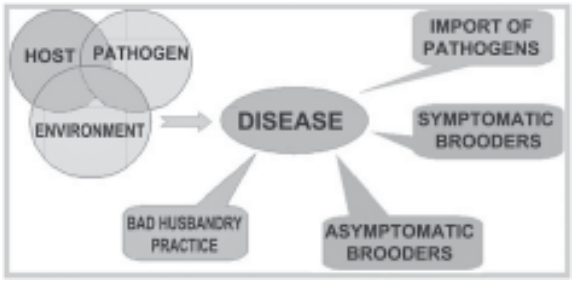
## Introduction

50 per cent of global production of aquatic animals for human consumption comes from aquaculture, close to 90 per cent of which is produced by countries in the Asia-Pacific region. With the increase in culture of new aquatic animal species, new and emerging diseases are constantly being discovered.

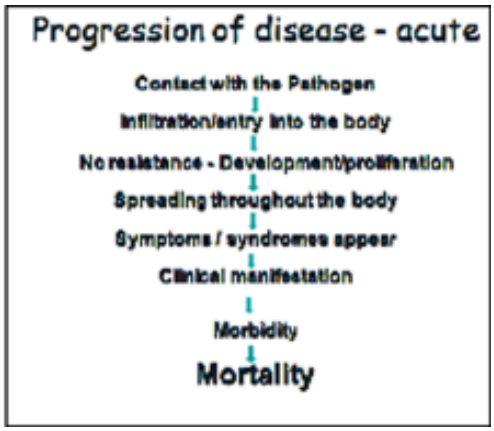
Diseases can be caused by a variety of factors, the most important being pathogens. Other factors contributing towards the development of disease conditions include stress, environmental/ water quality, physical agents, nutritional imbalance, toxins etc or a combination of these. Disease condition what we see is thus a complex situation resulting from the interaction/modification of the primary disease condition by these biotic and abiotic factors. The effect of diseases on animals range from reduced production to mortalities. In nature we are less aware of fish disease problems because sick animals are quickly removed from the population by predators, and moreover fish are much less crowded in natural systems than in captivity. Pathogens are always present in the environment and a delicate balance exists between the host, pathogen and environment (fig.1). Any changes in any of these factors may disturb the equilibrium and may lead to increasing or decreasing levels of disease.

The most obvious sign of disease in any system is the presence of dead or dying animals. However, careful observation can usually tell that fish are sick before they start dying because sick fish often stop feeding and may appear lethargic. Fish that are observed hanging listlessly in edges of the pond, gasping at the surface, abnormalities in the feeding pattern (poor feeding or overfeeding) or rubbing against objects indicate something may be wrong. These behavioral abnormalities indicate that the fish are not feeling well or that something is irritating them. In addition to behavioral changes, there are physical signs that indicate potential disease problems in fish. These include the presence of sores (ulcers or hemorrhages), ragged fins, or abnormal body confirmation (i.e., a distended abdomen or “dropsy” and exopthalmia or “poped up eyes” or bulged eyes). When these abnormalities are observed, the fish should be evaluated for the presence of diseases. Since disease in aquatic system is largely a management problem, the conventional preventive approach - “prevention is better than cure” – is the only viable option. Thus for tackling any disease condition, the first step is the correct diagnosis of the problem at the right time followed by suitable treatment and management schedules. If the diagnosis is faulty the result will be loss of animals along with wasted treatment efforts.




There are two broad categories of diseases that affect fish, infectious and non-infectious diseases. Infectious diseases are caused by pathogenic organisms present in the environment or carried by other fish. Majority of diseases affecting fishes are infectious, caused by opportunist viruses, bacteria, and parasites. These pathogens multiply in vast numbers in the fish, causing massive damage to the organism by depriving it of life-essential substances and/or by producing ichthyotoxic substances. In both cases the health of the fish is affected and results in diseases, unless appropriate treatment is given. In contrast, non-infectious diseases are caused by environmental problems, nutritional deficiencies, or genetic anomalies; they are not contagious and usually cannot be cured by medications.

Based on their nature, diseases can be classified into Acute and Chronic. In the case of chronic infections the development is very slow, usually may or may not show pathology/symptoms and may remain in the host's body for a prolonged period serving as a reservoir/carrier while in acute infections the infection progresses rapidly resulting in mortality.


The time lag between the entry of pathogen into the body and the development of symptoms is known as the incubation period which varies depending upon various biotic and abiotic factors. Healthy fish have the natural ability to defend themselves against infections and even if the pathogens gains entry into the body, a strong immunity/host resistance prevents the pathogen from establishing. Stress, however, slows down the immune system making the fish weak and unable to defend itself. The equilibrium between the host and pathogen is of key importance in the process and if the pathogen dominates, disease symptoms start appearing.

**Infectious diseases**

Issues regarding aquatic animal health are usually referred to the International Disease Commission (*Office International des Epizootices* [OIE]). Its mission is to inform governments on the occurrence and course of diseases throughout the world and of ways to control these diseases, to co-ordinate studies devoted to the surveillance and control of animal disease, and to harmonize

regulations for trade in animals and animal products among its 158 member countries. In Asia, the OIE and the Network of Aquaculture Centres in Asia-Pacific (NACA) collaborate to create an OIE/ NACA Regional Information System for Aquatic Animal Diseases, aimed at promoting the health of aquatic animals. The *OIE Aquatic Animal Health Code*, first published in 1995, provides international standards for the safe trade of amphibians, crustacean, fish, molluscs and their products. The international fish disease commission has listed more than 17 diseases of concern among the farmed finfishes (OIE, 2006)

**OIE Listed diseases in Fishes**

- Epizootic haematopoietic necrosis
- Infectious haematopoietic necrosis
- *Oncorhynchus masou* virus disease
- Spring viraemia of carp
- Viral haemorrhagic septicaemia
- Channel catfish virus disease
- Viral encephalopathy and retinopathy
- Infectious pancreatic necrosis
- Infectious salmon anaemia
- Epizootic ulcerative syndrome
- Bacterial kidney disease (*Renibacterium salmoninarum*)
- Enteric septicaemia of catfish (*Edwardsiella ictaluri*)
- Piscirickettsiosis (*Piscirickettsia salmonis*)
- Gyrodactylosis (*Gyrodactylus salaris*)
- Red sea bream iridoviral disease
- White sturgeon iridoviral disease
- Koi herpesvirus disease

**Viral Diseases in aquacultured finfishes**

Viral diseases have not been considered earlier to be a significant factor in marine and brackish water culture, but there have been many reports indicating the existence of viral diseases which cause severe mortalities in fin fishes. Among the various fish viruses, infectious pancreatic necrosis (IPN) virus which was reported back in 1940 in salmonid hatcheries is very well studied. IPN virus is an RNA virus, affecting young ones of salmonids in hatcheries causing mortality ranging from 60-100%. Other well-characterized fish viruses (e.g., channel catfish virus, *Onchorhynchus masou* virus) can also cause significant losses in aquaculture. Lymphocystis disease has been viewed as a serious problem in sea bass culture. The disease caused by an iridovirus, infects connective tissue cells and is characterized by nodular white swellings (cauliflower like) on fins or body. It is more common in marine and brackish water fishes.

The global expansion of finfish aquaculture has led to the discovery of several new viruses. Many of these are endemic among native populations and opportunistically spill-over to infect fish in

aquaculture facilities. The following are the major emerging fish virus diseases that cause significant losses in aquaculture and are expanding in host or geographic range (Table 1).

Infectious haematopoietic necrosis (IHNV) is an OIE notifiable disease, considered as an important pathogen of farmed rainbow trout (*Oncorhynchus mykiss*) in the USA. Through contaminated eggs, the disease reached out to Europe and Asia, where it emerged to cause severe losses in farmed rainbow trout, an introduced species.

Viral haemorrhagic septicaemia (VHS) is another emerging disease caused by a fish rhabdovirus. Viral haemorrhagic septicaemia virus is also considered as an important cause of mortality in rainbow trout reared in aquaculture.

Spring viraemia of carp (SVC) is caused by a fish rhabdovirus. More recently, SVC has spread out to many geographic regions of the world and has been associated with very large losses in common carp and Koi carp.

Infectious salmon anaemia (ISA) is caused by a virus of the family Orthomyxoviridae. An emerging disease of farmed Atlantic salmon, caused outbreaks with high mortality among Atlantic salmon reared in Norway. The virus was incriminated as the etiological agent of the hemorrhagic kidney disease of farmed Atlantic salmon along the Atlantic coast of Canada and the USA.

Epizootic haematopoietic necrosis is caused by a large DNA virus (EHNV) under the family Iridoviridae. First appeared in Australia where it caused mortalities among cultured rainbow trout and redfin perch.

Red sea bream iridoviral disease is caused by red sea bream iridovirus (RSIV), has a host range of at least 31 species of marine fish. Similar viral diseases were reported from new hosts and other geographic areas of Asia and the etiological agents were novel iridoviruses including: infectious spleen and kidney necrosis iridovirus (ISKNV) from cultured mandarinfish (*Sinaperca chuatsi*) in southern China and sea bass (*Lateolabrax* sp.) iridovirus (SBIV). In addition to causing outbreaks associated with severe necrosis and high mortality in a wide range of cultured marine fish, these viruses have emerged to affect freshwater species such as the African lampeye (*Aplocheilichthys normani*) and dwarf gourami (*Colisa lalia*).

Viral nervous necrosis (VNN) has emerged to become a major problem in the culture of larval and juvenile marine fish worldwide. Initially described as a cause of substantial mortality among cultured barramundi (*Lates calcarifer*) in Australia where the disease was termed vacuolating encephalopathy and retinopathy, the condition was shown to be caused by a small, icosahedral virus. The disease is listed by the Office International des epizooties (OIE) as a major problem in the production of marine fish worldwide during the last decade. To date, the disease has been reported in at least 30 fish species, with the greatest impact being in sea bass and is known to cause the disease in groupers, pleuronectids, snappers, white bass, sea bream, Atlantic halibut, large mouth bass and freshwater aquarium fishes. Adult fish are known to carry the virus which does not produce clinical manifestations in the host. VNN is the first OIE listed viral pathogen reported from India in farmed *Lates calcarifer.*

The disease caused by Koi Herpes Virus (KHV) is one of the most classical examples of an emerging disease of fish. Koi herpesvirus (KHV) is a highly contagious viral disease that cause

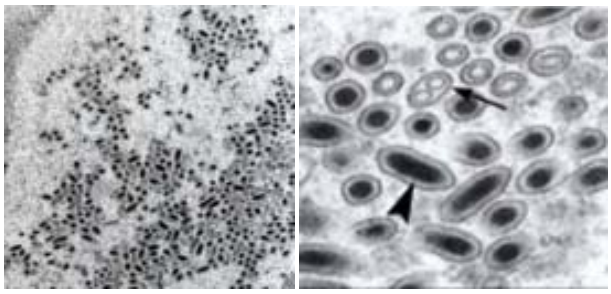
significant morbidity and mortality in common carp (*Cyprinus carpio*) and its ornamental subspecies, the Koi carp. KHV is a member of the genus Cyprinivirus in the family Alloherpesviridae and affects fish of various ages, but fry is more susceptibile. It causes 80-100% mortality in susceptible populations, with clinical signs of disease most commonly being expressed when water temperatures are between 22° and 27 °C. As with other herpes viral infections, KHV is believed to remain in the infected fish for life; therefore, exposed or recovered fish should be considered as carriers of the virus.

**Table 1.** Emerging viral pathogens of finfish.

| Virus | Abbreviation | Genome | Taxonomic classification[1] | Known geographic distribution | OIE listed[2] |
|---|---|---|---|---|---|
| *DNA viruses* | | | | | |
| Epizootic haematopoietic necrosis virus and other ranaviruses | EHNV | dsDNA | *Iridoviridae, Ranavirus* | Australia, Europe, Asia, North America, Africa | Yes |
| Red sea bream iridovirus | RSIV | dsDNA | *Iridoviridae, Megalocytivirus* | Asia | Yes |
| Koi herpesvirus | KHV | dsDNA | *Alloherpesviridae, Cyprinivirus* | Asia, Europe, North America, Israel, Africa | Yes |
| *RNA Viruses* | | | | | |
| Infectious haematopoietic necrosis virus | IHNV | (−) ssRNA | *Mononegavirales, Rhabdoviridae, Novirhabdovirus* | Europe, North America, Asia | Yes |
| Viral haemorrhagic septicaemia virus | VHSV | (−) ssRNA | *Mononegavirales, Rhabdoviridae, Novirhabdovirus* | Europe, North America, Asia | Yes |
| Spring viraemia of carp virus | SVCV | (−) ssRNA | *Mononegavirales, Rhabdoviridae, Vesiculovirus* | Europe, Asia, North and South America | Yes |
| Infectious salmon anaemia virus | ISAV | (−) ssRNA | *Orthomyxoviridae, Isavirus* | Europe, North and South America | Yes |
| Viral nervous necrosis virus | VNNV | (+) ssRNA | *Nodaviridae, Betanodavirus* | Australia, Asia, Europe, North America, Africa, South Pacific | No |

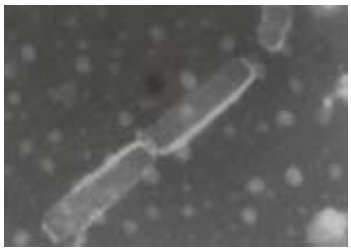
## Viral diseases in farmed shrimp

Shrimp is the largest single seafood commodity, accounting for 17% of all internationally traded fishery products and 75% of the production comes from aquaculture. Viral diseases have had a major impact on the shrimp farming industry resulting in major crop failures and economic losses. Since 1981, a succession of new viral pathogens has emerged in Asia and the Americas, causing mass mortalities and threatening the economic sustainability of the industry. Almost all shrimp pathogens exhibit vertical and horizontal transmission. The disease is the result of a massive viral amplification that follows exposure to various biotic and abiotic stress factors. Among the infectious diseases of cultured shrimp, virus-caused diseases stand out as most significant. The pandemics due to the penaeid viruses, WSSV (White Spot Syndrome Virus), TSV (Taura Syndrome Virus) and YHV (Yellow Head Virus), have cost the penaeid shrimp industry billions of dollars in lost crops, jobs, and export revenue. The following are the viruses listed by the OIE as causing notifiable diseases of marine and freshwater shrimp.



White spot syndrome first emerged in China in 1992, was soon after reported in Taiwan and Japan and has since become panzootic throughout the shrimp farming regions of Asia and the America. It is the most devastating disease of farmed shrimp ever reported. White spot syndrome virus (WSSV) is a large, enveloped, ovaloid DNA virus with a

flagellum-like tail and helical nucleocapsid that has been classified as the only member of the new family Nimaviridae, genus Whispovirus. Although first emerged in farmed kuruma shrimp (*Penaeus japonicus*), WSSV has a very broad host range amongst all decapod crustaceans, all of which appear to be susceptible to infection. All farmed marine (penaeid) shrimp species are highly susceptible to white spot disease, with mass mortalities commonly reaching 80–100% in ponds within a period of 3–10 days.



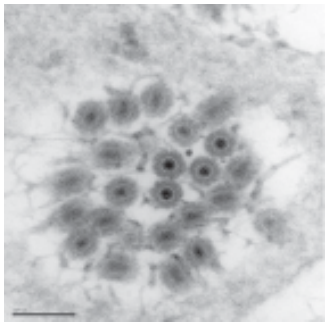
Monodon Baculo Virus (MBV) is the first shrimp virus to be recorded from India. The virus has become enzootic among the shrimp population of the country. It affects the hepatopancreatic tissues and only acute infections are a cause of worry. Non lethal screening of broodstock using PCR can be effectively used as a management strategy to prevent the entry of the virus into the rearing facility

Taura syndrome first emerged in white Pacific shrimp (*P. vannamei*). The disease spread rapidly throughout most shrimp farming regions of Central and South America and has now spread throughout much of Asia. Mortalities in the acute phase can be as high as 95% but surviving shrimp remain infected as a potential source of virus transmission. The susceptible host range of TSV is far more restricted than that of WSSV but includes most farmed marine shrimp species. The rapid spread of TSV has been attributed to the international trade in live shrimp.

Yellow head virus (YHV) is the most virulent of shrimp pathogens, causing total crop loss within several days of the first signs of disease in a pond. It first emerged in black tiger shrimp (*P. monodon*) in Thailand in 1990 and has since been reported in most major shrimp farming countries in Asia. YHV is now considered as a complex of six closely related viruses infecting *P. monodon*. Gill-associated virus (GAV) is a far less virulent virus that emerged to cause mid-crop mortality syndrome in farmed P. monodon in Australia in 1996.

Infectious hypodermal and haematopoietic necrosis was first detected in Hawaii in 1981, causing mass mortalities in blue shrimp (*Penaeus stylirostris*). IHHNV was found to be widely distributed in both *P. stylirostris* and *P. vannamei* shrimp throughout farming regions of the Americas and in the wild shrimp population of the Gulf of California. In Asia, IHHNV is endemic and occurs commonly in *P. monodon* which appears to be the natural host and in which it does not cause disease and has no impact on growth or fecundity.

Infectious myonecrosis is one of the most recent emerging viral diseases of marine shrimp. It first appeared in farmed *P. vannamei* and has subsequently spread throughout coastal regions of north-east Brazil and to Indonesia, Thailand and China Shrimp with the acute form of the disease display various degrees of skeletal muscle necrosis, visible as an opaque, whitish discolouration of the abdomen. Surviving shrimp progress to a chronic phase with persistent low-level mortalities. Several farmed marine shrimp species have been reported to be susceptible to infection but disease has only been reported in white Pacific shrimp. The practice of co-cultivation of white Pacific shrimp and black tiger shrimp is likely to present opportunities for adaptation and further spread of the disease. The trans-continental spread of the disease has certainly been due to the voluminous trade in *P. vannamei* broodstock.



White muscle disease is another emerging infection of the giant freshwater shrimp Macrobrachium rosenbergii. The causative agent is an RNA virus (Machrobrachium noda virus, (*Mr*NV), and the disease can affect larvae, postlarvae and early juvenile stages, causing up to 100% mortalities within 5–7 days of the first gross signs which include a white or milky appearance of abdominal muscle. Adults are resistant to the disease but can be persistently infected and transmit the infection vertically. Marine shrimp (*Penaeus monodon, P. japonicus* and *P. indicus*) have been shown to be susceptible to infection but did not develop disease, while artemia and some species of aquatic insects appear to be vectors.

**Table II.** Emerging viral pathogens of marine and freshwater shrimp.

| Virus | Abbreviation | Genome | Taxonomic classification[1] | Year emerged | Known geographic distribution | OIE listed disease[2] |
|---|---|---|---|---|---|---|
| *DNA viruses* | | | | | | |
| Monodon baculovirus | MBV | dsDNA | *Baculoviridae* | 1977 | Asia-Pacific, Americas, Africa | No |
| Baculoviral midgut gland necrosis virus | BMNV | dsDNA | *Baculoviridae* | 1971 | Asia, Australia | No |
| White spot syndrome virus | WSSV | dsDNA | *Nimaviridae, Whispovirus* | 1992 | Asia, Middle-East, Mediterranean, Americas | Yes |
| Infectious hypodermal and haematopoietic necrosis virus | IHHNV | ssDNA | *Parvoviridae, Densovirus* | 1981 | Asia-Pacific, Africa, Madagascar, Middle-East, Americas | Yes |
| Hepatopancreatic parvovirus | HPV | ssDNA | *Parvoviridae, Densovirus* | 1983 | Asia-Pacific, Africa, Madagascar, Middle-East, Americas | No |
| *RNA viruses* | | | | | | |
| Yellow head virus | YHV | (+) ssRNA | *Nidovirales, Roniviridae, Okavirus* | 1990 | East and Southeast Asia, Mexico | Yes |
| Taura syndrome virus | TSV | (+) ssRNA | *Picornavirales, Dicistroviridae* | 1992 | Americas, East and Southeast Asia | Yes |
| Infectious myonecrosis virus | IMNV | (+) ssRNA | Totivirus (unclassified) | 2002 | Brazil, Indonesia, Thailand, China | Yes |
| Macrobrachium rosenbergii nodavirus | MrNV | (+) ssRNA | Nodavirus (unclassified) | 1995 | India, China, Taiwan, Thailand, Australia, Caribbean | Yes |
| Laem-Singh virus | LSNV | (+) dsRNA | Luteovirus-like (unclassified) | 2003 | South and Southeast Asia | No |
| Mourilyan virus | MoV | (−) ssRNA | Bunyavirus-like (unclassified) | 1996 | Australia, Asia | No |

## Bacterial diseases

A great number of aquatic bacteria are opportunists and do not cause diseases under normal environmental conditions. However, under the stressful conditions of intensive fish farming, these opportunistic bacteria can cause bacterial diseases. Bacteriae may be the primary cause of disease, or very often may be secondary invaders, taking advantage of a breach in the fish's body covering (skin) or compromised immune system. Opportunistic pathogenic bacteria can proliferate and spread disease throughout the fish's body fluid or tissues if they are absorbed through the gills or gut, or gain entry via the skin. This is known as a systemic infection. Many clinical signs of bacterial diseases of cultured marine finfish are similar. Typical signs of bacterial diseases in fish include: red and inflamed areas on the body and fins, raised scales, skin ulcers, exophtalmos, dropsy or swollen abdomen, fin rot etc. Additionally, affected fish may be lethargic

and anorexic. There may be lesions or haemorrhages in organs and/or a build-up of bloody fluid in the abdominal cavity (ascites).

The majority of bacterial infections are caused by Gram-negative organisms including the following pathogenic genera: *Aeromonas, Citrobacter, Edwardsiella, Flavobacterium (Flexibacter), Mycobacterium, Pseudomonas*, and *Vibrio.* Bacterial diseases caused by pathogenic vibrios are responsible for larval mortalities and economic losses in finfish and shellfish hatchery rearing systems. Among the Gram-positive bacteria, *Streptococcus* has been shown to cause disease in fishes. So far very few bacterial diseases have been reported from cultured marine finfish in Southeast Asia, and from India there is no report on the maricultured species. Commonly encountered bacterial diseases in fish are:

***Aeromonas hydrophila:*** Gram negative bacteria, **c**auses Bacterial Hemorrhagic Septicemia. The most common symptom is hemorrhage in skin, fins, oral cavity and muscles with superficial ulceration of the epidermis.

***Pseudomonas fluorescens:*** Lesions similar to *A. hydrophila* with hemorrhagic septicemia. *P. anquilliseptica* causes a serious mortalities in Japanese eels with a septicemia resulting in petechial hemorrhage on fins and tail and ulceration of the skin.

***Vibrios:*** **G**ram negative rods, mainly marine. Cause hemorrhage in the skin of the tail and fins, ulceration of the skin, muscles and serosal surfaces. Deep skin ulcers and necrotizing myositis also seen. *V. alginolyticus* / *V. anquillarum* / *V. salmonicida* are the commony encountered species.

***Edwardsiella tarda*** *(Edwardsiella* septicemia) affects primarily channel catfish but also observed in many other species. Is the most serious pathogen involving the eel culture in Asia. Lesions are similar to that of *A. hydrophila* with small cutaneous ulcers and hemorrhage in the skin and muscle.

***Edwardsiella ictaluri*** (Enteric septicemia of catfish): Affects primarily fingerlings and yearling catfish. The most characteristic external lesion is the presence of raised or open ulcers on the frontal bone of the skull between the eyes (Hole in the head disease).

***Aeromonas salmonicida*** (Furunculosis, Ulcerative disease of goldfish): septicemia with hemorrhage in the muscles and other sites. Subcutaneous swelling that often causes an ulcerative dermatitis observed.

***Yersinia ruckeri*** (Enteric red mouth): Generally affects salmonids and rainbow trout are the most susceptible. Symptoms include septicemia with exophthalmus, ascites, and hemorrhage and ulceration of the jaw, palate, gills and operculum, musculature and serosal surfaces of the intestines.

***Streptococcus iniae:*** Disease of tilapia, hybrid striped bass and rainbow trout. *S. iniae* develops either as an acute fulminating septicemia with hemorrhage of the fins, skin, and serosal surfaces and ulceration. The chronic form is limited primarily to the central nervous system. *S. iniae* is a problem primarily of closed recirculating culture system, probably associated with overcrowding and poor water quality.

***Flexibacter columnaris*** (Columnaris disease or Saddleback disease): a highly communicable and serious disease of young salmonids, catfish and many other fish. Lesions usually first appear as small white spots on the caudal fin and progresses towards the head. The caudal and anal fins may become severely eroded. As the disease progresses, the skin is often involved with numerous gray white ulcers. Gills are a common site of damage and may be the only affected area. The disease is frequently associated with stress conditions.

**Bacterial Gill Disease:** Is caused by a variety of bacteria. *Flexibacter columnaris, Flexibacter psychrophilus* and various species of *Flavobacterium* are the primary bacteria involved in this disease. Fry are most susceptible to the disease.

***Renibacterium salmoninarum (Bacterial Kidney Disease)*** A serious disease of salmonids caused by Gram positive bacillus. The disease follows a slow course with clinical signs not present until the fish is well grown. The fish may exhibit exophthalmus, skin darkening, and hemorrhage at the base of the fins. Cutaneous vesicles and ulcers may also develop.

***Mycobacterium species*** (Tuberculosis): Gram positive, acid fast rods. *M. marinum, M. chelonei* and *M. fortuitum* are the most common Mycobacterium species involved. Infects almost all species of fish. Clinical signs of tuberculosis are quite variable, the most common signs being anorexia, emaciation, vertebral deformities, exophthalmus, and loss of normal coloration.

***Nocardia* sp. :** Gram positive filamentous rods. Chronic disease characterized by raised granulomatous masses in the mouth, jaw, gills and skin

**Fungal Diseases**

Fungal infections as such have not been considered to be an important factor in marine and brackish water fish culture, but there have been reports implicating various fungal pathogens in fish mortalities. They are opportunistic pathogens/secondary invaders which typically colonize exposed damaged tissue. Fungal infections are of 2 types, superficial and deep seated or systemic. The superficial ones, generally referred to as Saprolegniasis are by far the most commonly observed in fish. These are primarily freshwater fungi, however isolates have been reported from estuarine fishes also. Systemic fungal infections are considered to be more dangerous and difficult to cure. Ichthyophoniasis, a systemic fungal disease caused by *Ichthyophonus* sp. is capable of producing mortalities of epizootic proportions in wild marine fish populations. Epizootic Ulcerative Syndrome (EUS) is a pathogenic, invasive, fungal infection caused by the fungus, *Aphanomyces invadans* in Asian freshwater and estuarine fishes. It causes skin ulceration and death in over 30 species of commercially important cultured and wild fishes both in freshwater and estuarine habitats.

**Parasitic Diseases**

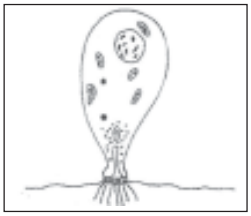
Parasites are generally opportunistic pathogenic organisms, causing diseases under congenial conditions. A variety of parasites are found infecting marine finfishes. Most of the parasites are

normally non pathogenic and do not cause diseases. When large numbers are present in the fish host, they can cause diseases and/or can become a major contributing factor to disease development. They are generally divided into two groups: ectoparasites, which live on the outside of the host (including the gills, mouth, skin and fin surfaces), and endoparasites, which live in the tissues, blood and/or organs (including the gastrointestinal tract). Based on their organization they are also classified into protozoans (single celled) and metazoans (multicellular).

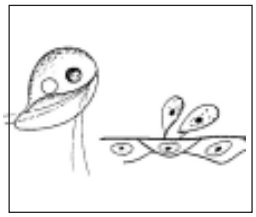
Protozoan parasites are a large heterogeneous group of organisms capable of causing severe damage to any marine fish in intensive culture systems. Protozoans have been reported to be pathogenic to grouper, sea bass and snapper fry and fingerlings at the nursery phase or grow-out phase during the first week after stocking in the cages. The ciliated protozoans, *Cryptocaryon irritans* and *Trichodina* spp., are highly pathogenic to newly introduced fish fry and juveniles in the cage environment. Various species of monogenean parasites are also known to cause serious production losses and mortalities in finfish culture. Other metazoan parasites like digenetic trematodes, nematodes, acanthocephalans and crustaceans are also of importance in finfish culture. Parasitic isopods, can under favourable conditions cause serious damages in cage cultured fin fishes. The pathogenicity of each parasite differs for each species of fish, as well as for each stage of the growth cycle and also the culture site. Some are highly host specific while many others are non-specific thus making their control of outbreaks very difficult.

**Amoebiasis:** Different species of amoebas have been incriminated in amoebic diseases in fish, of which *Neoparamoeba* spp. Is an important one. In heavy infections, the parasites elicit epithelial hyperplasia, resulting in complete fusion of secondary lamellae and subsequent gill disfunction. The disease is common in salmon.

**Amyloodiniosis:** known as “velvet disease”, the causative agent is *Amyloodinium ocelatum*, an ectoparasite on the skin and gills of fish. The parasite is least host-specific and affects almost all species of fish. Apart from the velvet appearance, clinical signs consist of anorexia and scratching. Massive infections are frequently associated with mortalities, both in mariculture and sea aquaria, mainly at high temperatures.



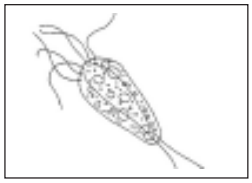
**Ichthyobodosis or Costiasis:** *Ichthyobodo* spp. (formerly known as *Costia*) are the agents of this disease infecting the gills and skin. *I. necator* is the species parasitizing salmonids in freshwater, but a different species is considered to be present in marine fish. Affected fish appear thin and lethargic, and may show a grey-whitish pellicle on skin, epidermic erosion or even haemorhages or ulcers, as well as gill hyperplasia and edema. Coastiasis is prevalent in different fish species, mainly in larval and juvenile stages.



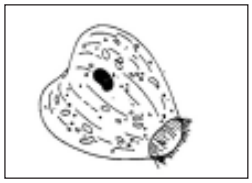
**Cryptobiasis:** *Cryptobia* spp., have a direct life cycle. Marine ectozoic species include *C. branchialis* and *C. eilatica.* In heavy infections, the parasites produce gill hyperplasia and epithelial destruction, with subsequent respiratory impairment. External signs are anorexia and skin darkness.

**Flagellates:** Some species of these genera parasitize internal organs of fish. *Cryptobia iubilans* is the only pathogenic intestinal species, common in cichlids. *Trypanoplasma* spp. and *Trypanosoma* spp. include parasites of the bloodstream and of tissues, with indirect life cycles (leeches are the

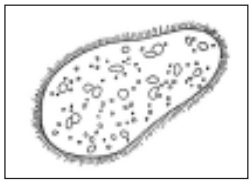
main vectors). The best known is *Trypanoplasma salmositica* (frequently referred as *Cryptobia samositica*) producing cryptobiasis of salmonids. Clinical signs consist of exophthalmia, splenomegaly, hepatomegaly, abdominal distension with ascites, anemia and anorexia. Mortality is dependent on fish stocks and species, but may be high in juveniles. The disease has severe impact in salmonid cultures in North America.



**Hexamitiasis:** *Hexamita* spp. are parasites of the intestine and gall bladder of freshwater fish, mainly salmonids but also cyprinids and ornamental fish. Hexamitiasis, typical of weak fish, is frequent as a secondary infection. Affected fish can show nervous behaviour, and internally the intestine may appear pale. Mortalities can occur in fry and juveniles.



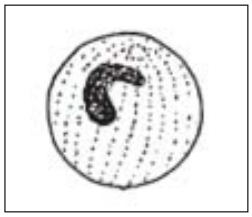
**Chilodonellosis:** Most *Chilodonella* spp. are free living, but some of them are serious pathogens of freshwater fish, causing heavy loses in aquaria and in cultures. Under favourable conditions they proliferate in the gills and skin of affected fish. The gills suffer hyperplasia, degeneration and necrosis, and respiration is drastically impaired. On the skin they may virtually cover the body surface.



**Tetrahymena:** Commonly called “Guppy Killer Disease.” Caused by a pear-shaped, ciliated, free-living/parasitic protozoan, common in crowded conditions and in water containing excessive organic debris. Severe infections can lead to mortalities.

**Cryptocaryosis:** *Cryptocaryon irritans*, a parasite of gills and skin, is the causative agent of this disease. External signs consist of white spots and excess mucus or ulcers on the skin and impairment of respiratory function. Gill histopathology consist of inflammation, haemorrhages, hyperplasia and lamellar destruction. This ciliate is a typical marine fish parasite affecting commercial and ornamental fish and producing high mortality in culture conditions. Outbreaks appears mainly at high temperatures.

**Trichodiniasis:** Fish trichodinids include mainly *Trichodina* spp., *Trichodinella* spp. and *Tripartiella* spp. These peritrichid ciliates are more commensals than genuine ectoparasites, but can produce different damages in massive infections. The fish show a grey-blue turbid layer on the skin. Respiratory function can be impaired in gill infections. Trichodinids parasitize a lot of freshwater and marine fish species.

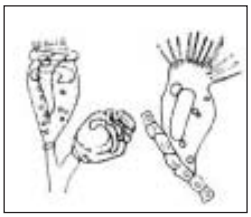


**White spot disease:** *Ichthyophtirius multifiliis* produces the well known white spot disease or ich. The most characteristic external sign is the presence of white spots on the skin and gills, due to parasite trophonts located under the upper layer of the skin. Affected fish can rub or flash and show breathing problems. In heavy infections the typical white spots are visible with the naked eye. The disease is widely distributed in many freshwater fish species, mainly in aquaria and culture conditions, in which it can produce epizootics. Mortality is mostly dependent on fish size and infection intensity.

**Scuticociliatida:** Several species of the genera *Uronema*, *Phylasterides* and *Miamiensis* have been recorded as facultative parasites of different fish. External signs include skin lesions or ulcers and

pigmentation changes, but the parasite frequently invade the body muscle and the internal organs, which become destroyed by this histophagous parasite. Nervous system can also be colonised, which can be accompanied by erratic swimming, equilibrium loss or lethargy. The disease cause severe infections and outbreaks in some cultured fish and mortalities can reach 100% of some affected stocks.

**Surface fouling Diseases:** Caused by a variety of ectocommensal peritrich ciliates. Usually these diseases are never considered serious, but in exceptional cases, along with other pathogens, they can cause considerable damage. In any healthy fish, peritrich ciliates will be present in small numbers, but does not usually cause any harm to their hosts and behave like typical ectocommensals. They attach to the surface of the fish, sometimes giving rise to heavy mat-like outgrowths. In its efforts to overcome the irritation/suffocation the animals rub/scratch their bodies resulting in bruises or open wounds on the skin, which again attract secondary invaders. *Epistylis, Ambiphrya, Capriana* etc are examples of ectocommensal ciliates infestibg fish.The most common ectocommensal found infesting shrimp is *Zoothamnium* sp.



**Endoparasitic Protozoans**

**Coccidiosis:** Many species of coccidia infect freshwater and marine fishes with variable pathologies. The genera *Eimeria, Goussia* and *Cryptosporidium* include the species more frequently reported from cultured fish. In freshwater fish, *G. carpelli* parasitizes different cyprinids and *E. anguillae* is typical of eels. In marine fish, *E. sparis* and *G. sparis* have been reported.

**Cryptosporidiasis:** Fish *Cryptosporidium* spp. affect mainly larvae and juveniles, with deleterious effects not always very evident, but resulting in poor condition. *C. molnari* is more frequent in seabream than in seabass.

**Microsporidiosis:** Microsporea are represented in fish by different genera, mainly *Enterocytozoon*, *Glugea*, *Loma*, *Pleistophora* and *Tetramicra*. In freshwater fish, *Pleistophora* and *Loma* are relatively frequent. Among cultured marine fish, there have been several reports of *Plesitophora senegalensis* in gilthead seabream, whereas *Glugea* sp. and *Tetramicra brevifillum* have been found in turbot. Pathological concern of microsporidiosis in fish is dependent on location and infection intensity.

**Myxosporea (myxosporidiosis) :** Myxosporea include numerous genera and species, most of them parasites of fish. Some species are well know pathogens for freshwater fish and marine fish. The most pathogenic species belong to the genera *Ceratomyxa*, *Myxobolus, Myxidium, Spaherospora*, *Enteromyxum, Kudoa, Tetracapsuloides* and *Sphaerospora*. In freshwater fish the most significant diseases are whirling disease, PKD, sphaerosporosis and ceratomyxosis. Myxosporea reported from cultured marine fish include species of the genera *Ceratomyxa, Enteromyxum, Kudoa, Lepthoteca, Sphaerospora and Sinuolinea*.

**Whirling disease is caused by *Myxobolus cerebralis* (*Myxosoma cerebralis*):** Clinical signs include dark coloration of the posterior part of the body and abnormal swimming in spiral, followed

by skull deformation and spinal curvature. Almost all salmonid species can be infected, but susceptibility is very variable according to the species.

**Proliferative kidney disease (PKD):** The causative agent, formerly known as PKX, has been recently identified as *Tetracapsuloides bryosalmonae* (syn. *Tetracapsula bryosalmonae*, *T. renicola*). The parasite is highly pathogenic and can produce a severe disease in rainbow trout, with 30-50% mortality. External clinical signs are abdominal swelling, darkening and exophthalmos. Internally, a kidney enlargement is observed, accompanied by ascites in advanced cases.

***Spaherospora renicola:*** Is widely distributed in intensive cultures of cyprinids, mainly *Cyprinus carpio*. Spores and sporogonic stages are located in the renal tubules, but proliferative stages appear in the blood and can reach the swimmbladder, causing inflammation. In the kidney tubules it produces dilatation, atrophy and necrosis of the epithelium, with subsequent impairment of renal function, making it a serious pathogen.

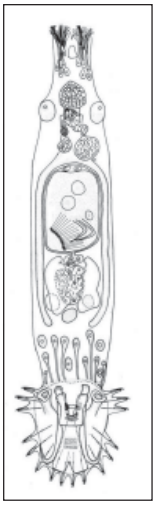
**Ceratomyxa :** The genus *Ceratomyxa* include a lot of marine species, though they have been rarely associated with significant pathological problems. The main species recorded in cultured marine fish are *C. diplodae, C. labracis* and *C. sparusaurati*. *C. diplodae* and *C. labracis* are quite frequent in wild and cultured seabass. They are not usually associated with clinical disease, but they can induce several histopathological lesions in the gall bladder and neighboring tissues.

***Ceratomyxa shasta:*** Is an important pathogen, causing serious loses in cultured and wild populations of salmonids on the west coast of North America. Intestine is the target organ and parasites can be observed in the epithelium, eliciting lymphocytic infiltration, hyperplasia and necrosis. In advanced stages of the infection, parasites spread to other organs and fish become anorexic, lethargic, and show abdominal swelling, ascites and exophthalmia. Significant mortalities can occur, depending on fish species, as susceptibility is variable.

***Enteromyxum* spp. :** Two species of this genus have special pathological concern for marine fish of high commercial value, and both parasitize the digestive tract of infected fish. *Enteromyxum leei* previously known as *Myxidium leei*, produces enteromyxosis in sparids. The parasite invades the intestinal tract causing severe chronic enteritis, frequently followed by emaciation and death. *E. scophtahlmi* is an important pathogen of turbot cultures, as mortalities can reach 100 % of the affected tanks or stocks, with subsequent economical impact.

***Kudoa* spp:** These marine myxosporeans infect the muscle of many marine fish forming plasmodial cysts. Heavy infections can cause unsightly white cysts or soft texture in filets. with subsequent lowering of market value. In aquaculture, *Kudoa* infections have been described in salmonids and *Seriola*.

**Sphaerospora:** *Sphaerospora dicentrarchi* is a histozoic parasite with an affinity for the connective tissue of gall bladder and intestine. It is usually a chronic infection, without external clinical signs, though massive infections have been associated with extensive mortalities in juvenile fish. *S. testicularis* infects the testicular tissues. Heavy infections can result in parasitic castration of valuable broodstock fish. In very heavy infections, the parasite invades the serosa and other organs, producing abdominal swelling and ascitis.



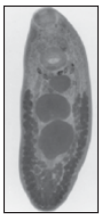
**Monogenea :** Members of Monogenea, mostly ectoparasites of gills and skin, can cause different degrees of damage in parasitized fish. Mortalities may appear in moderate or heavy infections, mainly in juvenile fish, increasing with water temperature. Clinical signs include lethargy, anoxia, loss of appetite and scratching. Excess mucus, opacity, and even ulcers or haemorrhages may appear. Gill histopathological signs include focal hyperplasia, lamellar fusion, haemorrhages and inflammatory infiltration. Monogeneans are usually very host specific, though in certain culture conditions some species can be found in unusual hosts. Monogenea include 2 main groups, *Monopisthocotylea* (with a simple adhesive disc) and *Polyopisthocotylea* (with a complex adhesive disc including clamps and hooks). Among *Monopisthocotylea* the most significant species for cultured fish are *Gyrodactylus* spp., *Dactylogyrus* spp., *Diplectanum* spp. and *Furnestinia* spp. *Polyopisthocotylea* include several species of pathological concern for fish cultures, most of them belonging to the family Microcotylidae, and some to Heteraxinidae.

***Gyrodactylus* spp.:** causing gyrodactylosis, are mainly typical from freshwater fish. Some species are very pathogenic for salmonid fish, specially *G. salaris*, considered the most pathogenic species.

***Dactylogyrus* spp.:** This genus include numerous species, mostly parasites of freshwater fish. Cyprinids are the main hosts of these monogeneans, but fish of many other families are also affected. The pathologic significance is very dependent on the species and intensity of infection.

***Diplectanum* spp.:** The best known species of this genus are *D. aequans* and *D. laubieri*, parasites of *D labrax*. Their dispersion is very wide in the Mediterranean and Atlantic areas, mostly coinciding with seabass distribution. *D. aequans* is considered more pathogenic, mainly for juveniles and brood stocks.

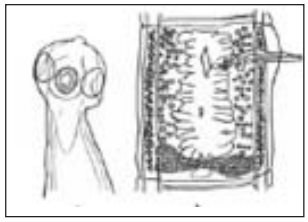
**Microcotylosis:** In the last years, microcotylosis has affected severely the sparid cultures, causing important loses. Besides the gill dysfunction usually associated with monogenosis, microcotylids produce increased damage due to their haematophagus condition, causing anemia and poor fish condition.



**Trematodes:** *Diplostomum* spp.: The metacercarial phase of these digeneans parasitizes the eye of fish, though it can be occasionally found in other organs, including the brain. Numerous fish species are susceptible to metacercaria of Diplostomatidae. Clinical signs consist of cloudiness of eye lens, leading to crystalline opacity and blindness. Dark body coloration can be also observed. Acute mortality is very rare, but poor condition is frequent, probably due to the problems with locating food.

**Sanguinicolosis:** Members of the family Sanguinicolidae are parasites of the circulatory system of fish. Adults are located in the circulatory system. Eggs can accumulate in blood vessels, and are quite frequent in the gills, producing vascular obstruction. Inflammatory response are common in moderate or severe infections. Found in freshwater and marine fishes.

**Cestodes:** These platyhelminthes may parasitize fishes in larval or adult stages, sometimes causing diseases in cultured fish with variable economic impact. Most species causing disease in fish of economic importance fall within three orders: Caryophyllidea (*Caryophyllaeus* and *Khawia*),

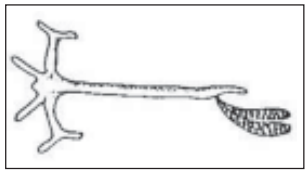


Pseudophyllidea (*Bothriocephalus, Diphillobothrium, Ligula* and *Triaenophorus*) and Proteocephalidea (*Proteocephalus*). Cestodes in fish usually do not cause mortality, though poor condition is frequently observed, mainly in heavy infections. Adult cestodes of the genera *Caryophyllaeus* and *Khawia* parasitize the digestive tract of cyprinids and salmonids, producing different degrees of damage and economic impact in the cultures. In heavy infections, abdominal swelling and poor condition can be observed, mainly in small fish. *Bothriocephalus* spp. and *Eubothrium* spp. are parasites of freshwater and marine fish. *Eubothrium spp.* are frequent in salmonids. *Triaenophorus spp.* can cause severe pathology in fish. Fish are usually the final hosts, but some small fish may act as reservoirs of certain species. Larval stages (plerocercoids) of *Diphyllobothrium* spp. parasitize the muscle and visceral organs of different freshwater fish. Mammals are the final hosts of these tapewormes, which can also infect humans.

**Nematodes:** Nematodes are common intestinal parasites of fish and can be found abundant in wild species. In some cases the fishes can act as intermediate hosts and may harbour larval nematodes, encysted beneath the skin, musculature or coelomic cavity.

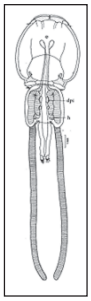
**Acanthocephalans:** Acanthocephalans are a group of endoparasitic helminths commonly found in both marine and freshwater fishes and are known to cause pathological conditions in many fin fishes. Total loss/degeneration of the intestinal villi and formation of granular tissues and capsule formation affect the digestive and absorptive efficiency of the animal and in heavy infections they can cause occlusion of the gut. Heavy infection with *Tenuiproboscis* sp. have been observed in the red snapper, *Lutjanus argentimaculatus*. Similarly *Pomphorhynchus* sp. have been known to infect many fish species in European countries.

**Crustaceans:** The main parasitic crustaceans of commercial fish belong to the groups Copepoda and Isopoda. Among Copepoda, species of the genera *Argulus*, *Caligus, Ergasilus, Lernanthropus, Lernaea, Lerneaocera* and *Lepeophtheirus* (sea lice) parasitize different freshwater and marine fish. They are located on the gills, bucal cavity and skin and produce different degrees of damage, even mortality, depending on the fish species and degree of invasion. Clinical signs include occasional rubbing, decrease of condition and gill damage leading to respiration problems. Inflammed wounds, ulcers and mucous excess can be produced as a consequence of crustacean bites, even affecting muscle. Salmons affected by sea lice may show small white-grey spots. In addition, crustaceans can carry or facilitate other infections.

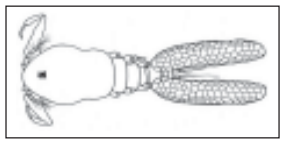


***Lernaea :*** Known commonly as “Anchor worm,” is a common copepod parasite which infects many species of ornamentals. They get their name from the attachment organ which is a highly modified structure resembling the anchor on a ship which is buried in the host’s musculature. A raised ulcer usually develops at the point of attachment, creating an opportunity for secondary infection with pathogenic bacteria.

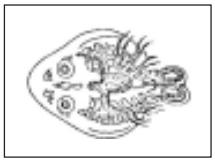
**Sea lice***:* are marine ectoparasites that feed on the mucus, epidermal tissue, and blood of host marine fish. *Lepeophtheirus salmonis* is more host specific and is considered as the most important



sea lice species in farmed and wild Atlantic salmon. Sea lice cause physical and enzymatic damage at their sites of attachment and feeding which results in abrasion-like lesions that vary in their nature and severity depending upon a number of factors like host species, age and general health of the fish. Sea lice infection itself causes a generalized chronic stress response in fish since feeding and attachment cause changes in the mucus consistency and damage the epithelium resulting in loss of blood and fluids, electrolyte changes, and cortisol release. This can decrease salmon immune responses and make them susceptible to other diseases and reduces growth and performance.



**Ergasilus:** Also known as 'gill maggot' is small in size and attacks the gills and sometimes skin of fish, appears as whitish-green threads hanging out of the fish's gills. Heavy infestations result in severe gill damage, emaciation, anemia and death usually due to secondary bacterial infection.



**Argulus:** commonly known as "Fish Louse", have a flat, distinctive shape and appearance, are found attached to the skin and fins by means of its suckers. Feed on the body fluids and are especially harmful to small fish. Reddish lesions occur at the site of attachment, and this opens the up the skin to secondary bacterial and fungal infections.

**Isopods**: Different Isopoda have been reported, mainly in sea fish, including *Nerocyla orbygnyi*, *Anilocra physodes*, *Gnathia* and *Paragnathia,* parasitizing seabass, seabream and other sparids, *Seriola* spp., or mugilids. Clinical signs include lethargy, anorexia and respiratory difficulties, as a consequence of gill damage and necrosis. *Cirolana fluviatilis* has been observed causing high mortalities in juveniles of sea bass reared in cages. The picture is frequently complicated by secondary bacterial infections. Mortality can appear mainly in juvenile fish.

**Diseases of Molluscs:** Compared to the European countries, every little is known about the diseases of molluscs from the Indian subcontinent. The following are the OIE listed molluscan diseases (OIE, 2006).

- *Bonamia ostreae*
- *Bonamia exitiosa*
- *Marteilia refringens*
- *Perkinsus marinus*
- *Perkinsus olseni*
- *Xenohaliotis californiensis*
- Abalone viral mortality

**Perkinsosis**: Except *Perkinsus olseni* none of the above OIE listed pathogens/parasites of molluscs have been reported from India. *P. olseni,* has been reported from various host species including the pearl oyster, *Pinctada fucata* and *Crassostrea madrasensis* from the Indian sub continent.

**Non-infectious diseases:** Non-infectious diseases can be broadly categorized as environmental, nutritional, or genetic. Environmental diseases are the most important and may be caused by low dissolved oxygen, high ammonia, high nitrite or natural or man-made toxins in the aquatic environment etc. Managing proper water quality will enable us to prevent most of these. Nutritional diseases can

be very difficult to diagnose. Deficiency of various essential micro nutrients including vitamins can cause a variety of nutritional diseases. The condition seems to disappear when the deficient feed is discarded and a new feed provided. Genetic abnormalities include conformational oddities such as lack of a tail or presence of an extra tail. Most of these are of minimal significance; however, it is important to bring in unrelated fish for use as brood stock every few years to minimize inbreeding.

**Prevention, Treatment and Control:** The cornerstone of disease prevention is the creation and maintenance of optimum rearing conditions. Good sanitation practices in combination with Quarantine & Biosecurity measures can help a great deal in reducing the incidence of diseases. Treatment of animals in aquaculture is not a viable proposition and preventive approaches is the only option left.

## Conclusion

When compared to the past decades, the threat faced by aquaculture is from an array of new/ emerging diseases, and the risk is on the rise. The alarming rate of emergence of new diseases has been driven primarily by anthropogenic influences, the most important of which have been associated with the global expansion of aquaculture. Farming involves displacement from their natural habitat to an environment that is new and often stressful, the use of feeds that are sometimes live and often unnatural, coupled with and high stocking densities futher stresses the animals. This provides opportunities for the existing and emerging pathogens to establish themselves in the hosts leading to diseases. The growth in aquaculture and increasing international trade has resulted in the rapid movement of aquatic animals and their products, with associated risks of the trans-boundary movement of pathogens. Due to the immense export potential, more and more entrepreneurs are venturing into the field of aquaculture and with the intensive nature of culture practices and frequent trans-boundary introductions of many exotic species, new diseases and pathogens are bound to affect this industry. Since chemotherapy/treatment options will definitely reduce the economic viability of the ventures and affect environmental health, it is always better and safe to adopt a proactive approach through better health management practices for the prevention/control of diseases.

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